Diversity Reception of 920MHz RFID Reader Antenna in Smart-Shelf System

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***Abstract*— A two-dimensional communication sheet is used as a receiving antenna of a smart-shelf system. Radio frequency identification (RFID) is the protocol used in this system to read the tag that includes information of the goods on the smart-shelf system. In this report, the diversity reception where the termination condition is switched between open and short circuits is proposed to improve the diversity gain in the low sensitivity area. The simulation and experimental results are shown.**

Index Terms — RFID, antenna, smart-shelf system

I. Introduction

RFID is one of the most promising technologies for wireless identification systems and sensor network systems. Two-dimensional communication sheet is capable of increasing area of the read and write of the RFID system in the smart-shelf system, which can be utilized not only in the management and administration of the books and documents, but also widely in inventory and security management in retail store [1][2]. The two-dimensional transmission sheet was also used in sensor networking [3-5], localization [6][7], and power transmission [8][9]. It was shown the straight and meandering microstrip lines mounted on the bookshelf was used as the leaky wave transmission line to enhance the electromagnetic coupling between the RFID reader and tags, where the characteristic impedance of the microstrip line is 50 ohms and the microstrip line is terminated by 50 ohm load. A two-dimensional communication sheet [3][8] was also used as the leaky wave transmission line in the smart-shelf system. However, because the standing wave exists in the two-dimensional communication sheet due to the impedance mismatch at edges of the sheet, the near field distribution of the sheet is non-uniform and the response performance of the tags is significantly degraded when the tags are in the area of the minimum of the standing wave.

In order to improve the transmitting efficiency, different shapes of the mesh on the two-dimensional transmission sheet were studied [8] to increase the leakage field of the transmission sheet. Some experimental and simulated results of the electric field distribution near the two-dimensional transmission sheet were presented in [9]. However, there are still some problems to be solved. For example, the receiving power of the tag depends on the position of tag on the sheet, and it becomes very small in some places of the sheet.

In order to solve this problem and to improve the response performance of the tags in the smart-shelf system using the two-dimensional communication sheet, 2-D communication sheet terminated with switched open/short termination and switching diversity reception is proposed. Numerical simulation of the proposed methods is performed using the method of moments, and the increase of the diversity gain due to the selection switching diversity reception and resistance termination are demonstrated by measurement result.

II. Two-dimensional communication sheet

A two-dimensional communication sheet is used as a RFID reader antenna in smart-shelf system. The objectives with RFID tags put on the sheet can be managed by the RFID system, any objective removed from the sheet can be detected in real time. The geometry of the sheet consists of a conducting mesh layer, dielectric substrate layer and a conducting ground plane, as shown in Fig. 1.

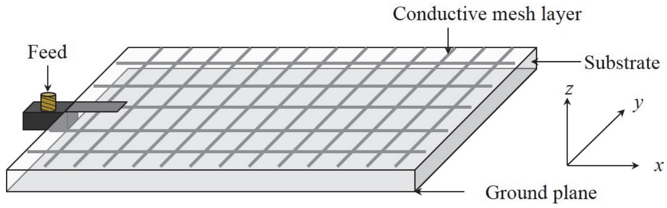

Fig. 1. Geometry of two-dimensional communication sheet.

The sheet is analyzed using the method of moments numerically. In this numerical simulation, the size of the sheet is 800 mm × 110 mm × 2 mm. The width of the microstrip line of the sheet is 1 mm and the distance between each line of the mesh is 6 mm. Because the dielectric constant of the substrate is $\varepsilon_r = 1.3$ which is very low, and dielectric effect is omitted in this simulation. The mesh layer and ground plane are both assumed to be perfect electric conductor. The ground plane is assumed an infinitely conducting plane. The sheet is fed by a voltage source between the mesh and the ground plane and the working frequency is 920 MHz.

The RFID tag antenna is assumed to be a linear wire antenna located vertically above the sheet so that it is mainly coupled with the sheet by z-component of the electric field. Therefore, only the z-component of the electric field is shown in this paper. The $|E_z|$ distribution at z = 30 mm is shown in Fig. 2., where the input power is 1 watt. Because the sheet is terminated with the open circuit, a standing wave distribution of electric field is observed.

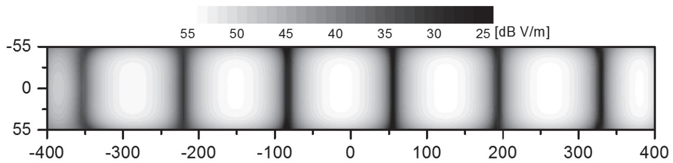

Fig. 2. $|E_z|$ on the sheet at z = 30 mm.

III. DIVERSITY RECEPTION

In order to solve the problem, diversity reception is proposed to improve the electric field distribution. Diversity reception is made by switching the termination condition of the sheet between open and short circuit as shown in Fig. 3 to change the electric field distributions on the sheet.

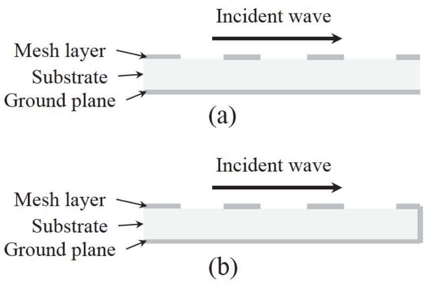

Fig. 3. Sheet terminated by (a) open and (b) short termination.

A two-dimensional communication sheet with size 400 mm × 110 mm was numerically analyzed. The cumulative distribution function (CDF) of the electric field on z-component on the sheet terminated with open/short circuit and used diversity reception are shown in Fig. 4, respectively. It is shown that the electric field on the sheet used diversity reception is larger than the sheet terminated with open/short circuit by 10 dB at 10% CDF and 23 dB at 0.1% CDF. It demonstrates that using diversity reception by switching the termination between open/short circuits can increase the receiving level by tags.

In the case of sheet length is 400 mm, the amplitude of electric field on z-component on the sheet terminated with open circuit is larger than short circuit, but the relation changes when the length of the sheet changes because the input power is fixed while the input impedance strongly depends on the sheet length. However, the effect the diversity reception using open/short termination can be similarly demonstrated for arbitrary sheet length.

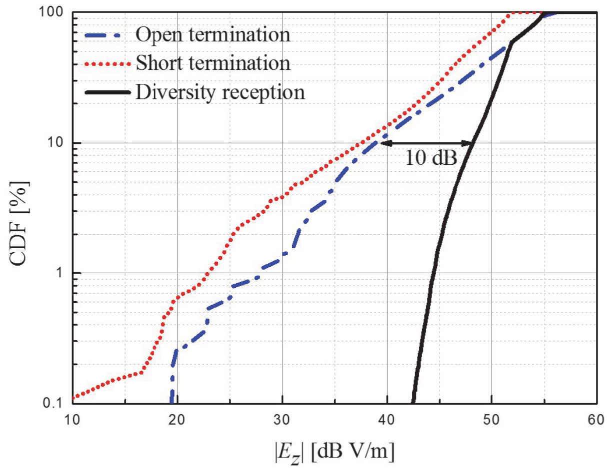

Fig. 4. CDF of the $|E_z|$ of diversity reception compared with that of open and short termination.

IV. EXPERIMENTAL RESULTS

In this section, a two-dimensional communication sheet provided by Teijin Limited is terminated with open and short circuit to change the electric field distribution on the sheet.

Fig. 5 shows the measurement system, which is composed of a signal generator (Agilent E4438C), a spectrum analyzer (Rohde/Schwarz FSU26), and a xyz 3-axis scanner. Because the near field distribution on the sheet is measured, in order to reduce the influence of a probe, a dipole antenna type optical electric field sensor (NEC/Tokin OEFS) was used to measure the near field. The dipole antenna type OEFS was moved by xyz 3-axis scanner scans above the two-dimensional communication sheet to measure the electric field on the sheet.

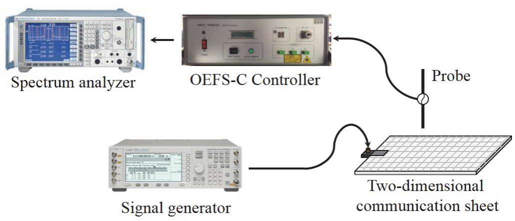

Fig. 5. Measurement system.

CDF of the received power on the sheet terminated by open, short circuit, and used diversity reception are shown in Fig. 6. It is shown that using diversity reception can increase the diversity gain of 5dB at 10%. It is demonstrated that the diversity reception can increase the diversity gain in the low sensitivity areas.

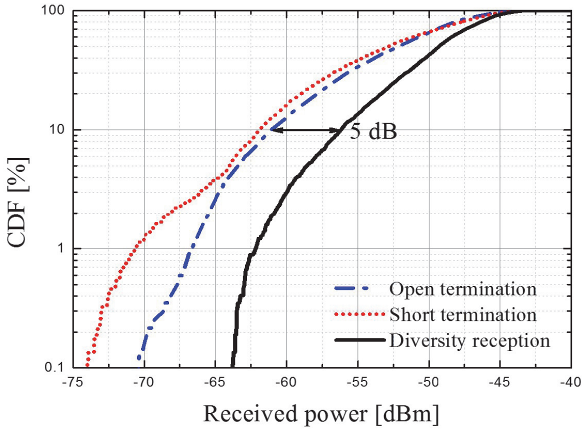

Fig. 6. CDF of the received power comparison between open terminations, short termination, and diversity reception.

V. CONCLUSIONS

The two-dimensional communication sheet terminated with open and short circuit has been analyzed numerically using the method of moments and the received power received by dipole antenna type OEFS has been measured. It has been found by simulation and experiment that the sheet using proposed diversity reception between open/short terminations can increase the receiving level of RFID system used in smart-shelf system. It was demonstrated that the proposed approach contributes to further improvement of the RFID system.

REFERENCES

[1] C. R. Medeiros, J. R. Costa, and C. A. Fernandes, "RFID Smart Shelf With Confined Detection Volume at UHF," *IEEE Antennas Wireless Propag. Lett.*, vol. 7, pp. 773-776, 2008.

[2] C. R. Medeiros, J. R. Costa, and C. A. Fernandes, "RFID Reader Antennas for Tag Detection in Self-Confined Volumes at UHF," *IEEE Antennas Propag. Mag.*, vol. 53, no. 2, pp. 39-50, Apr, 2011.

[3] H. Shinoda, "Sensor Networking based on Two-Dimensional Signal Transmission Technology," in *Proc. SICE-ICASE, 2006. Int. Joint Conf.*, Oct. 2006. pp. 4897-4869.

[4] T. Oota, A.-O. Lim, K. Hattori, Y. Kado and Bing Zhang "2D Communication Sensor Networks Using Single Frequency for Concurrent Power Supply and Data," in *Proc. Sensors, 2010 IEEE*, Nov. 2010, pp. 2016- 2021.

[5] H. Shinoda, Y. Makino, N. Yamahira, and H. Itai, "Surface Sensor Network Using Inductive Signal Transmission Layer," in *Proc. 4th Int. Networked Sensing Syst. Conf.*, Jun, 2007, pp. 201-206

[6] K. Nakatsuma, Y. Makino and H. Shinoda, "Node localization in the "Two-Dimensional Communication" Networks based on electric field pattern measurement," in *Proc. SICE Annual Conf.*, 2008, Aug. 2008, pp. 3380 - 3385.

[7] J.S. Choi, H. Lee, D.W. Engels, and R. Elmasri, "Passive UHF RFID Based Localization Using Detection of Tag Interference on Smart Shelf," *IEEE Tran. Syst., Man, and Cybernetics, Part C: Applications and Reviews*, vol. 42, no. 2, pp. 268-275, Mar. 2012.

[8] K. Minamizawa, Y. Makino, H. Shinoda, "Two-Dimensional Signal Transmission for Networked Sensing," in *Proc. SICE Annual Conf. 2005*, Aug. 2005, pp. 3816-3819,.

[9] N. Yoneyama and H. Arai, "A Power Collecting Circuit for WPT System using Sheet-like Waveguide," in *Proc. Microwave Workshop Series on Innovative Wireless Power Transmission: Technologies, Systems, and Applications (IMWS)*, 2012 IEEE MTT-S International, May 2012, pp.119-122.